

Final Technical Report
ONR grant N00014-91-J-1980
"Studies of the Norwegian Sea and North Atlantic"
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Submitted by:
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Summary

ONR grant N00014-91-J-1980 supported several collaborative field programs and related research on the marine geology and geophysics of the North Atlantic Ocean and Norwegian Sea by Hawaii Mapping Research Group (HMRG) of the University of Hawaii at Manoa, working with Naval Research Laboratory Code 7420 (H. Fleming) and Naval Oceanographic Office Code N344 (C. Ingram) during the period 1991-1995. A brief summary of the various projects, which included 7 expansions, is presented here:

The initial award, for period 01 June 1991- 31 December 1992, provided support for HMRG participation in four cruises on USNS *Kane*, conducting seafloor surveys in the Gulf of Cadiz (off Spain) and the Norwegian Sea (north of Iceland) during the summer of 1992. HMRG provided support to operate the new SEAMAP seafloor mapping system, which had recently been built by HMRG for NAVOCEANO. Subsequent expansions of the original award provided further support for survey programs in the North Atlantic and Norwegian Sea regions, including (1) providing waterguns for the 1992 cruises (P00001, \$50,409; 1/30/91-12/31/92); (2) providing analog seismic reflection instrumentation for the 1992 cruises (P00002, \$32,500; 5/1/92-12/31/92); (3) providing shipboard technical support for SEAMAP operations on two cruises in summer 1993 (P00003, \$32,208; 6/15/93-6/30/94); (4) carrying out special SEAMAP post-processing following the 1993 field program (P00004, \$30,000; 9/1/93-6/30/94); (5) producing special SEAMAP data products following the 1993 field program (P00005, \$59,284; 4/8/94-12/31/95); (6) providing shipboard personnel and instrumentation in support of three summer 1994 SEAMAP field programs (P00006, \$174,975; 4/15/94-12/31/95); and (7) providing shipboard personnel in support of two summer 1995 SEAMAP field programs (P00007, \$59,069; 5/1/95-12/31/95). In addition, a no-cost extension to 9/30/96 was provided to complete fabrication and delivery of sonar transducers, part of expansion P00006 of these funded efforts. The total award, therefore, extended from 6/1/91 - 9/30/96, with a total support level of \$1,188,445.00, and involved participation by University of Hawaii personnel in a total of 13 cruises in collaboration with the two U.S. Navy groups.

Although none of the work involving University of Hawaii personnel was classified at the time of participation, subsequent reevaluation of the status of data collected during operations carried out in 1993-1995 by the Naval Oceanographic Office resulted in retroactive classification of all information acquired in the course of field programs, as well as on the name of the operation. All data which was in Hawaii at the time of the retroactive classification decision was, therefore, returned to the Naval Oceanographic Office, and with the exception of information published in one abstract (Gardner et al, 1993, see publications section at end) which was approved for release in fall 1993, it is not possible to describe the field program results here, nor for University of Hawaii to publish any of the data collected therein. This is not the case, however, with the original 1992 cruise, from which all geophysical data was released to Alexander Shor for unclassified research by himself and his students (in collaboration with Naval Research Lab Code 7420), and publications resulting from that research are listed at the end of this document.

Summary of work completed: Kane cruises

The original award for this work supported 4 cruises on USNS *Kane* in summer-fall 1992. The first two cruises surveyed along the southwestern margin of Spain, working out of Rota, Spain, with the second cruise ending in Bergen, Norway. The third cruise surveyed the Jan Mayen Ridge, located north of Iceland in the Norwegian Sea; the fourth cruise concentrated on the Kolbeinsey Ridge northwest of

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Iceland. The third and fourth cruises both began from Bergen; the fourth cruise ended in St. Johns, Newfoundland.

Field programs in 1992 used the SEAMAP seafloor mapping system, a side-scan sonar and bathymetric mapping system developed and built by HMRG for the Naval Oceanographic Office (Code N344) under separate contract. Except for acceptance trials conducted in spring 1992 off Oahu, Hawaii, this project was the first use of SEAMAP, and the first leg included system checkout and testing as well as survey operations. It also served as training of NAVOCEANO personnel in operation of the mapping system. All four legs were collaborative among NRL Code 7420 (Henry Fleming), NAVOCEANO Code N344 (Carey Ingram) and University of Hawaii at Manoa; the University of Hawaii involvement was primarily in operation of the SEAMAP sonar, and secondarily in providing equipment and personnel for seismic reflection profiling (expansions P00001 and P00002 of this award). Overall responsibility for survey operations vested in the NAVOCEANO SNR from Code N344 (J. Herring for the first two cruises, J. Turcotte for the latter two). The NRL party chiefs were C. Nishimura (first cruise), M. Czarnecki (second cruise) and D. Chayes (cruises 3 and 4). University of Hawaii shipboard party chiefs were A. Shor (cruises 1, 3 and 4) and E. Halter (cruise 2). Cruise ID for NAVOCEANO for the four cruises were 271292 (cruises 1-2), 271392 (cruise 3) and 270193 (cruise 4). The first cruise began on July 20, 1992, in Rota, Spain, and the fourth cruise ended in St. Johns, Newfoundland, Canada, on November 6, 1992.

Although there were some operational problems associated with SEAMAP during the first two cruises, in general the system operated quite well, and surveys were completed in water depths ranging from 200 meters to greater than 4000 meters, providing full side-scan sonar and swath bathymetric coverage of most of the planned survey region, which lies immediately west of the Strait of Gibraltar. Study of the data from the surveys off Spain is not planned by University of Hawaii personnel, but will be primarily carried out by NRL Code 7420. Initial results were reported in Joseph et al, 1993, found in the publications list at the end of this report.

Cruise 3 operations were principally carried out over the Jan Mayen Ridge, a submarine plateau in the Norwegian Sea north of Iceland. This feature was found to consist of a series of relatively narrow, elongate slivers, probably of continental crust, and with numerous small canyons incising the margins of the plateau fragments (see Johnson et al, 1993 abstract in publications list). Analysis of Jan Mayen Ridge data is primarily being carried out by NRL Code 7420 scientists, with some collaboration by Shor, and publication of a paper on these results is anticipated in late 1997 or 1998.

Initial surveys over the Kolbeinsey Ridge began at the end of cruise 3, and were completed on cruise 4. Kolbeinsey Ridge is the active modern spreading center in this part of the Norwegian Sea, bounded to the north by Jan Mayen Fracture Zone and to the south by Iceland. The results of these surveys formed a major part of the Ph.D. research of Bruce Appelgate, at the time a graduate student of Shor's, and now the field program operations manager for HMRG. Dr. Appelgate's dissertation and the papers resulting from it, are identified in the publications section below; one of the three dissertation chapters was published in 1994, one is presently in the final revision stages following acceptance by the journal, and the third is expected to be submitted during February 1997. The results of these surveys provide a unique, high-resolution set of data over one of the slowest-spreading mid-ocean ridge segments surveyed to date, and demonstrate convincingly that non-transform overlapping spreading center offsets are quite important in the development of the morphology. The standard models for ridge growth predict that transform offsets would be much more common here, but none are observed between the north slope of Iceland and the Jan Mayen Fracture Zone.

Summary of work completed: 1993-1995 programs

As indicated previously, the classified status of data collected in the 1993-1995 programs carried out with NRL and NAVOCEANO under this grant precludes discussion of results. However, it is acceptable to briefly summarize here the use made of research funds; further information regarding these projects can, as needed, be obtained from either NRL Code 7420 (Henry Fleming) or NAVOCEANO Code N344 (Carey Ingram).

Expansion P00003 provided funds to include one HMRG data technician in 1993 field programs using SEAMAP. In addition to the data technician supported under this grant, Alexander Shor and Mark Rognstad of HMRG participated in the field program under Intergovernmental Personnel Assignments supported separately.

Expansions P00004 and P00005 provided funds for special processing and production of special data products from the 1993 cruise for post-cruise briefings for NAVOCEANO and NRL.

Expansion P00006 provided support for participation of one data technician in support of cruises in summer 1994, as well as providing spare parts, supplies and replacement parts for the SEAMAP system. As in the previous year, both Alexander Shor and Mark Rognstad also participated in the field program under separate support. Part of the support was for repairs and modifications to be made to the sonar arrays. As described below, delays and unavailability of the sonar arrays prevented this work being completed in either 1994 or 1995, and NAVOCEANO decided in consultation with HMRG to change this portion of the award, with HMRG acquiring newly-developed replacement sonar arrays in lieu of modifying the existing arrays.

Expansion P00007 provided support for engineer and electronics technician support of summer 1995 SEAMAP field operations by NAVOCEANO. Surveys in 1995 did not involve direct participation by Shor or Rognstad, and data processing did not involve University of Hawaii personnel.

The no-cost extension to September 1996 included rebudgeting, in consultation with NAVOCEANO, to acquire new, improved sonar arrays for SEAMAP.

Publications resulting from this award:

Doctoral dissertation

Appelgate, Bruce, 1995. Geophysical Investigations of the Reykjanes Ridge and Kolbeinsey Ridge Seafloor Spreading Centers. Ph.D. Dissertation, Department of Geology and Geophysics, University of Hawaii at Manoa. 86 pp.

Journal articles

Appelgate, Bruce, 1997 (accepted). Rapid reorientation of a slow seafloor spreading center: The structural evolution of Kolbeinsey Ridge since 10 Ma. *Geology*. [This paper is a revised version of Chapter 2 of Appelgate's Ph.D. dissertation, accepted 12/96 by *Geology*, and presently being revised.]

Appelgate, B., and A. N. Shor, 1994. The northern Mid-Atlantic and Reykjanes Ridges: Spreading center morphology between 55°50'N and 63°00'N. *Journal of Geophysical Research*, v. 99, p. 17935-17956. [This paper is Chapter 1 of Appelgate's Ph.D. dissertation.]

Appelgate, B., and A. N. Shor, 1997 (to be submitted). Axial structure and recent tectonics of the Kolbeinsey Ridge seafloor spreading center. *Journal of Geophysical Research*. [This paper is a revised version of Chapter 3 of Appelgate's Ph.D. dissertation, expected to be submitted 2/97.]

Published abstracts and conference proceedings

Appelgate, B., A.N. Shor, D. Chayes, L.E. Johnson and P.R. Vogt, 1993. Axial structure of the Kolbeinsey Ridge seafloor spreading center. American Geophysical Union 1993 Spring Meeting Abstract Supplement, p. 307.

Davis, R.B., M.H. Edwards, S.H. Zisk, A.N. Shor and E. Halter, 1993. New techniques for interactively processing and mosaicking various bathymetric and backscatter datasets. American Geophysical Union 1993 Spring Meeting Abstract Supplement, p. 307.

Gardner, J.M., A.N. Shor, P.R. Vogt and J. Herring, 1993. Late Quaternary sediment transport on the Upper Bear Island Fan: Recent SEAMAP side-scan sonar and bathymetric surveys off Norway. American Geophysical Union 1993 Fall Meeting Abstract Supplement, p. 343.

Halter, E.F., A.N. Shor, S.H. Zisk and M.R. Rognstad, 1992. HAWAII MR1 and SEAMAP: Two new systems for sea floor surveying. American Geophysical Union 1992 Fall Meeting Abstract Supplement, p. 543.

Johnson, L.E., P.R. Vogt, D. Chayes, B. Appelgate, L. Kajiwarra and A.N. Shor, 1993. Geophysical studies of the Jan Mayen Ridge, 70.16 N - 67.75 N. American Geophysical Union 1993 Spring Meeting Abstract Supplement, p. 307.

Joseph, D., A.N. Shor, E. Halter, C. Nishimura, M. Czarnecki, P. Vogt, C. Hones and D. Chayes, 1993. SEAMAP investigation of the Gulf of Cadiz and Gorringer Bank: The search for the boundary between the African and Eurasian plates. American Geophysical Union 1993 Spring Meeting Abstract Supplement, p. 307.

- Lingsch, S., and C. Robinson. 1994. A comparison of SEAMAP and Sea Beam bathymetry in the Jan Mayen Ridge. Marine Technology Society 1994 Annual Meeting (Proceedings), 7 pp.
- Rognstad, M.R., 1992. HAWAII MR1: A new underwater mapping tool. International Conference on Signal Processing and Technology, Boston, MA (Proceedings), p. 900-905.
- Whittaker, C.C., M. Rognstad and A.N. Shor, 1991. NAVOCEANO's new swath bathymetric and imaging system. Proceedings of the Marine Technology Society, New Orleans, LA.